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Technical note

The triple-window approach, without olecranon osteotomy or radial nerve exposure, to intra-articular distal humeral fractures extending into the humeral shaft

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1. Introduction

Various surgical approaches have been recommended to achieve open reduction and internal fixation of isolated intra-articular fracture of the distal humerus[3,10,11,13] and of humeral shaft fractures.[5,7] There is, however, no ideal solution to the very challenging surgical problems posed by intra-articular distal humeral fractures that extend to the distal third of the humeral shaft or that are associated with a concomitant humeral shaft fracture. Archdeacon[2] reported one such case treated with open reduction and internal fixation through a combined olecranon osteotomy and posterior triceps-splitting approach. Recently, Lewicky et al.[8] introduced a surgical technique to treat these complex fractures, using a combined olecranon osteotomy and a lateral paratricipital-sparing, deltoid insertion-splitting approach. According to these authors, all fractures were anatomically reduced and rigidly fixed with three plates in total; however, the clinical results were unclear and the approaches require very extensive surgical dissection, including olecranon osteotomy, splitting the posterior triceps and deltoid insertion, and radial nerve exposure. The purpose of the present report was to describe a minimally invasive triple-window approach to reduce and fix such difficult fracture patterns, without olecranon osteotomy or radial nerve dissection. We also present two cases with good clinical outcomes following this procedure.

2. Surgical technique

Operations were performed using regional or general anaesthesia and the supine position, with the arm to be operated abducted at 90° and supported on a lucent operating table. A sterile pneumatic tourniquet was applied.

With the elbow extended, the first incision was made measuring approximately 7 cm, starting distally from the tip of the medial epicondyle and proceeding proximally along the medial supracondylar ridge of the humerus toward the axillary line (Fig. 1). The ulnar nerve was isolated, released from the ulnar nerve groove and retracted posteriorly. The medial and anteromedial sides of the metaphyseal segment of the distal humerus were exposed through the interval between the brachial muscle and medial intermuscular septum. The common origin of the flexor muscles was dissected and reflected distally, leaving a 5-mm ligamentous cuff, to be resutured *in situ* after the operation. The periosteum was stripped and the anterior capsule was incised. The anterior articular surface of trochlea was then exposed.

The second incision measured approximately 8 cm, beginning distally from the lateral epicondyle and continuing proximally along the lateral supracondylar ridge of humerus toward the deltoid tuberosity (Fig. 2). The interval between the triceps posteriorly and the origins of the extensor carpi radialis longus and brachioradialis anteriorly was identified, and the lateral border of the humerus was exposed. The fragment of the lateral epicondyle was found to be laterally rotated by the extensor muscles. The anterior part of the common origin of the extensor muscles was dissected and distally reflected, exposing the radiohumeral joint.

With flexion of the elbow at approximately 70° and with anterior retraction of the biceps and brachialis muscles, the anterior side of the distal humerus was exposed. The articular fragments were identified, reduced and temporarily fixed with K-wires mostly through the lateral incision. Reduction of the articular surface was visually examined, mainly through the lateral incision, and a C-arm was used to examine the reduction. The reduced articular fragments were definitively fixed with a 4.5-mm cannulated screw introduced through the lateral incision along a guide-wire from the lateral to the medial condyle. The articular component of the distal humerus was then reduced to the humeral shaft. A 3.5-mm one-third tubular plate was applied to fix the

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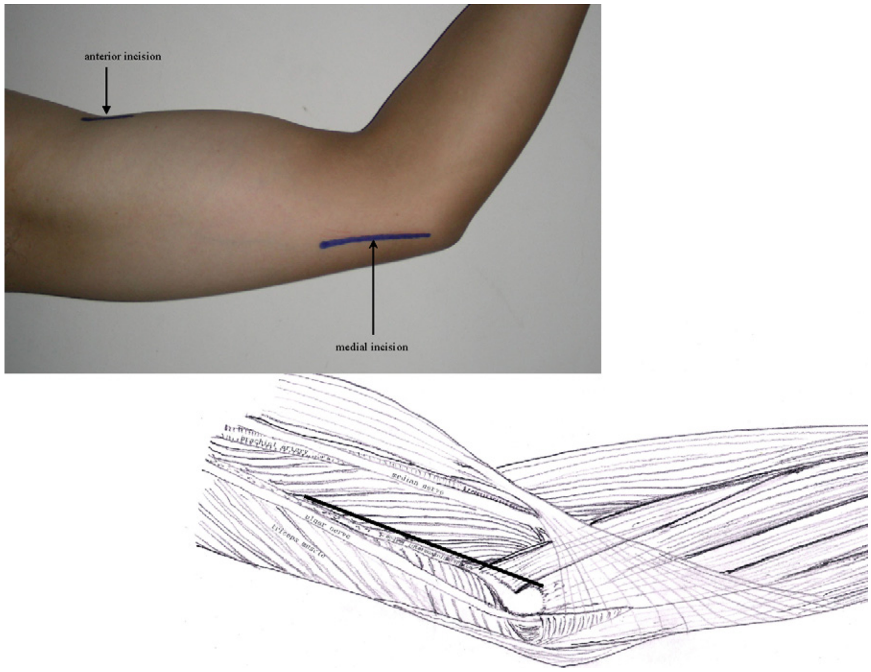

Fig. 1. Medial incision starts from the tip of the medial epicondyle and extends proximally along the medial epicondylar ridge.

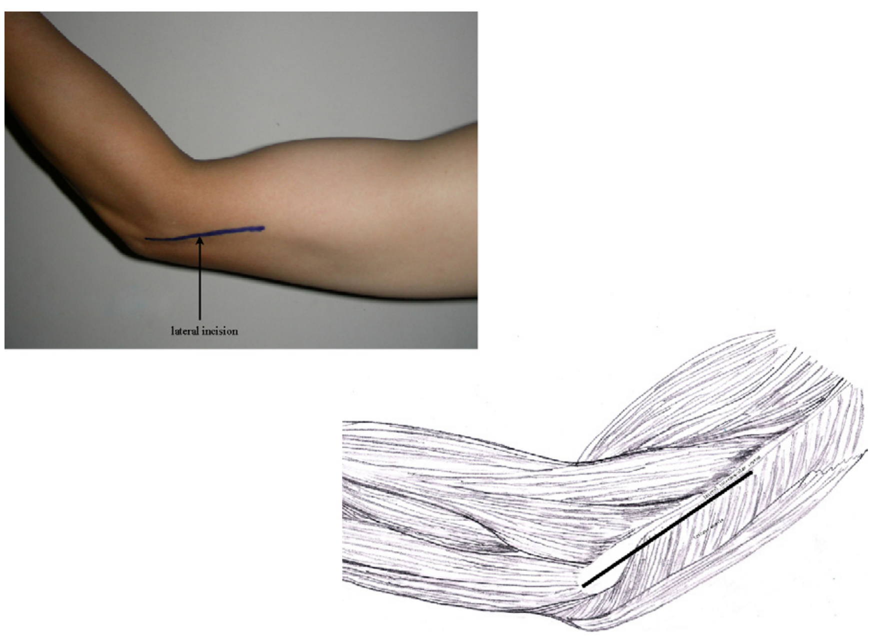

Fig. 2. Lateral incision begins from the lateral epicondyle and extends proximally along the lateral epicondylar ridge, not passing beyond the point where the radial nerve penetrates the lateral intermuscular septum.

medial column of the distal humerus to the humeral shaft through the medial incision.

At this point the tourniquet was deflated and removed. The third incision was made along the interval between the lateral border of the proximal part of the biceps brachialis muscle and the medial border of the deltoid muscle on the anterior side of proximal arm. The interval was proximal and medial to the deltoid tuberosity and the anterior side of the humerus here is subcutaneous. The incision was 3 cm in length and the dissection was carried down to the humerus. A extraperiosteal tunnel was prepared under the brachialis muscle using a narrow periosteal elevator from the proximal to distal direction, meeting the lateral incision of the elbow. A long, narrow 4.5-cm dynamic compression plate (DCP, 10–12 holes) was selected to fix the lateral column of the distal humerus to the humeral shaft. The distal part of the plate was contoured to match perfectly the shape of the anterolateral aspect of the distal humerus. The plate was then inserted under the brachialis muscle from the proximal incision and passed through the fracture site of the humeral shaft to meet the lateral incision. The proximal end of the plate was positioned on the anterior side of the proximal humeral shaft distal to the crest of greater tubercle, and the distal end of the plate was located on the anterolateral aspect of the distal humerus, not extending to the articular surface of the capitallette. The proximal and the distal ends of the plate were then fixed to the humerus with three screws in each end.

If the fragments showed no abnormal mobility, the dissected common origins of the flexor and extensor muscles were resutured. The wounds were closed after including a submuscular drainage tube on the anterior side of the distal humerus through an additional lateral stab incision. It was not necessary to expose the radial nerve or to further manipulate the ulnar nerve during the entire procedure.

After the operation, the affected elbow was immobilised in 90° of flexion by splinting for 3 weeks. Active shoulder movements were encouraged early after surgery, and active extension and flexion of the elbow started 3 weeks after removal of the splint.

3. Case reports

3.1. Case 1

A 44-year-old woman was severely injured during a road traffic accident. Radiographs showed a sagittally oriented intra-articular fracture of left distal humerus that extended into the distal third of the humeral shaft. Right acetabular fractures (bicolumnar) and tibial plateau fractures (Schatzker VI type) were also identified. Staged management was recommended, and the humeral fractures were treated first. In this case it was impossible to perform an open reduction and internal fixation of humerus fractures through the posterior approach introduced by Lewicky et al.[8] in the prone position because of the associated acetabular and tibial plateau fractures, and the triple-window approach was used. In the supine position, the distal intra-articular fractures were openly reduced by medial and lateral incisions without olecranon osteotomy. The humeral shaft fractures were closely reduced manually without exposing the radial nerve. The articular fragments were fixed by a cannulated screw and strengthened by a 3.5-mm lag screw added proximally to the olecranon fossa; the humeral shaft and the lateral column of the distal humerus were fixed by a 4.5-mm DCP placed proximally anteriorly and distally anterolaterally. A medially positioned 3.5-mm one-third tubular plate was used to increase the rigidity of the DCP; the two screws of the proximal end of the plate were inserted into the proximal fragment of the humeral shaft, and its two distal screws were inserted through the lateral fragment of distal humerus. The other fractures were surgically treated 7 days after the first operation. The woman was followed for 40 months after surgery; all of the fractures were united without infection, non-union or hardware failure. No sign of radial or ulnar nerve palsy was recorded. At the latest visit, the affected elbow demonstrated excellent flexion of 130° and extension of 10°. Pronation and supination of the forearm each of 90° were also recorded (Fig. 3).

3.2. Case 2

A 36-year-old woman, whose left upper extremity was injured in a fall, sustained an intra-articular fracture of the distal humerus and a proximal ulnar shaft fracture in combination with dislocation of the proximal radio-capitellar joint (Monteggia fracture). The distal humeral fracture was surgically reduced through medial and lateral elbow incisions, 6 days after the injury. The articular fragments were fixed with a 4.0-mm cannulated screw, and the articular component was fixed to the humeral shaft with a one-third tubular plate placed on the medial and a 3.5-mm reconstruction plate placed on the posterolateral side of the distal humerus. The proximal ulnar fracture was openly reduced through a posterior incision and fixed with a 3.5-mm limited-contact DCP. Subluxation of the radiocapitellar joint was revealed by post-operative radiography, and a plaster was applied with 100° flexion of the elbow and supination of the forearm. The plaster was removed 6 weeks after surgery and active exercise of the elbow and shoulder commenced.

The woman re-injured the arm in a second fall 3 months after the initial operation. A peri-implant fracture was identified at the proximal end of the plate positioned on the posterolateral side of the distal humerus. The distal intra-articular fracture was found to be clinically united. Non-operative measures, including manual manipulation under the C-arm and immobilisation with a splint, were initially selected to treat the fracture, but without success. Open reduction and internal fixation had to be carried out 3 days after the injury. The previous posterolaterally positioned plate was removed through the initial lateral incision, and the humeral shaft fracture was anatomically reduced and fixed with a 2.0-mm and a 1.5-mm K-wire. A contoured 10-hole 4.5-mm DCP was placed proximally on the anterior ridge of humerus and distally on the anterolateral side of the distal humerus to fix the fracture. Three screws were applied in the proximal and two in the distal end of the plate. The neglected subluxation of the radial head was re-reduced and fixed with a K-wire.

The affected upper extremity was immobilised with an abduction splint for 6 weeks after the second operation. Active movement of the elbow and shoulder began 6 weeks after removal of the splint and K-wire.

The woman was followed for 12 months after the second operation. By this time all of the fractures were found to have united, leading to optimal function of 120° flexion and 30° extension of the left elbow, with 90° pronation and 45° supination of the left forearm (Fig. 4).

4. Discussion

There is little literature on distal humeral fractures treated through combined medial and lateral elbow approaches. In this report, anatomical reduction of the articular surface of the distal humerus was performed through these approaches, as the intra-articular fracture patterns of the distal humerus in both cases presented were relatively simple. Only two main fragments affected the articular surface, the fracture lines involving the surface were in a sagittal orientation and the exposure and reduction of the intra-articular fractures did not require extensive dissection. Reduction of the anterior articular surface was evaluated directly by visual examination, and of the whole surface indirectly by reduction of the anterior cortex of the metaphyseal region of the distal humerus. When one fracture line in both regions was anatomically reduced, we assumed that the posterior articular surfaces were also anatomically reduced. Finally, reduction of the articular surface was confirmed under the C-arm.

In cases where distal intra-articular fractures were associated with or extended into humeral shaft fractures, the medial and lateral columns and humeral shaft should be fixed rigidly, so that early motion of the shoulder and elbow can be encouraged postoperatively. Lewicky et al.[8] reported that in such a case the humeral shaft was stabilised with a 4.5-mm DCP placed on the posterior side, the distal humeral fractures being fixed with a contoured reconstructive plate placed on the medial and lateral columns, which was considered to be the gold standard for fixation of intra-articular distal humeral fractures.[9,11] In this report, the articular fragments were mainly fixed with one 4.5-mm cannulated screw inserted into the trochlea, which is similar to previous reports.[6] However, in our report a one-third tubular plate, small enough to place exactly on the medial side of distal humerus, was applied to fix the medial column of the distal humerus to the shaft. The rigidity of fixation between the main fragments was strengthened either with an additional lag screw placed in the supracondylar region, or with ordinary cortical screws inserted through the holes of the medial plate. The fixation of the articular component of distal humerus to the humeral shaft was mainly achieved by a 4.5-mm DCP. According to Apivatthakakul et al.,[1] humeral shaft fractures could be treated with an anteriorly placed plate without exposure or iatrogenic palsy of the radial nerve. Their clinical report also demonstrated that the fractures could be treated with the minimally invasive plating osteosynthesis technique, in which the fracture is reduced by manual manipulation and fixed with an anteriorly placed straight plate without interfering with the radial nerve.[12] For our cases, when fixation of the secondary or combined humeral shaft fractures was performed, the radial nerves were not exposed during either the initial or the second operation. There was no any sign of iatrogenic radial nerve palsy.

Carlan et al.[4] concluded that the radial nerve is at risk of injury in fractures of the humerus and subsequent operative fixation in two areas: the first along the posterior mid-shaft region, and the second along the lateral aspect of the humerus in its distal third from nearly 10.9 cm proximal to the lateral epicondyle as far as the level of the proximal aspect of the metaphyseal flare.[4] When the lateral approach was applied to expose the distal humerus, the dissection was performed through the incision posteriorly to lateral intermuscular septum, with the elbow flexed to avoid stress injury to the radial nerve. When a 4.5-mm DCP was applied to fix both the humeral shaft and lateral column, it was carefully contoured so that its proximal part was accurately positioned on the anterior side of the humeral shaft with its most proximal hole located proximal to the deltoid tuberosity, and its distal part was located on the anterolateral aspect of the lateral column of the distal humerus. When a sub-muscular tunnel was prepared, the periosteal elevator was maintained close to the anterior cortex of humeral shaft.

On the basis of our limited experience of two cases, we suggest that it is premature to recommend this procedure for routine application. More data are needed to prove clinical efficacy and

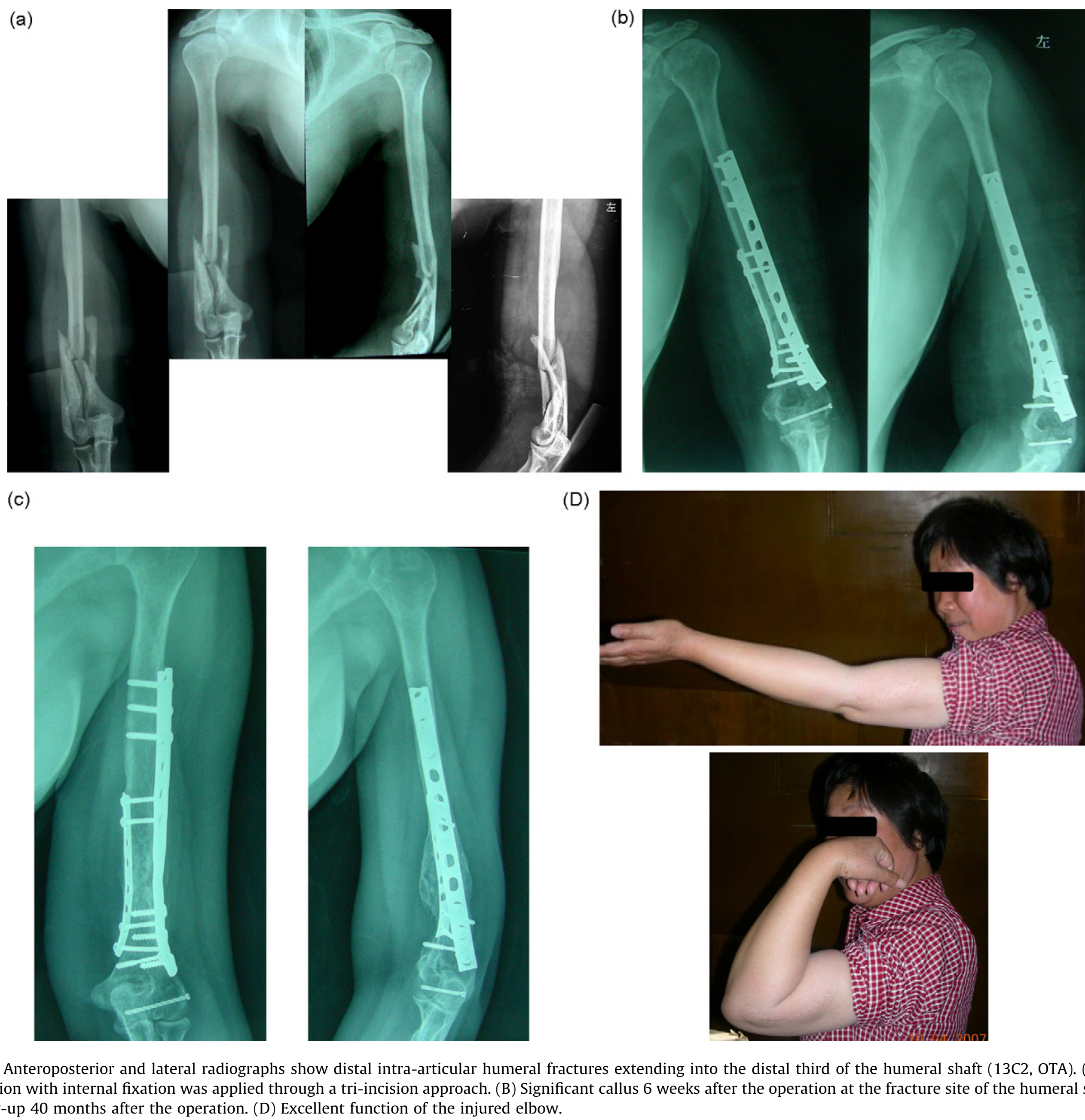

Fig. 3. Anteroposterior and lateral radiographs show distal intra-articular humeral fractures extending into the distal third of the humeral shaft (13C2, OTA). (A) Open reduction with internal fixation was applied through a tri-incision approach. (B) Significant callus 6 weeks after the operation at the fracture site of the humeral shaft. (C) Follow-up 40 months after the operation. (D) Excellent function of the injured elbow.

utility. However, for cases with relatively simple patterns of distal intra-articular humeral fracture that are combined with or extend into the humeral shaft, this procedure could be an effective treatment alternative. For treatment of comminuted intra-articular fractures combined with or extending onto the humeral shaft, the surgical technique introduced by Lewicky et al. is recommended. More clinical cases should to be examined to confirm our findings.

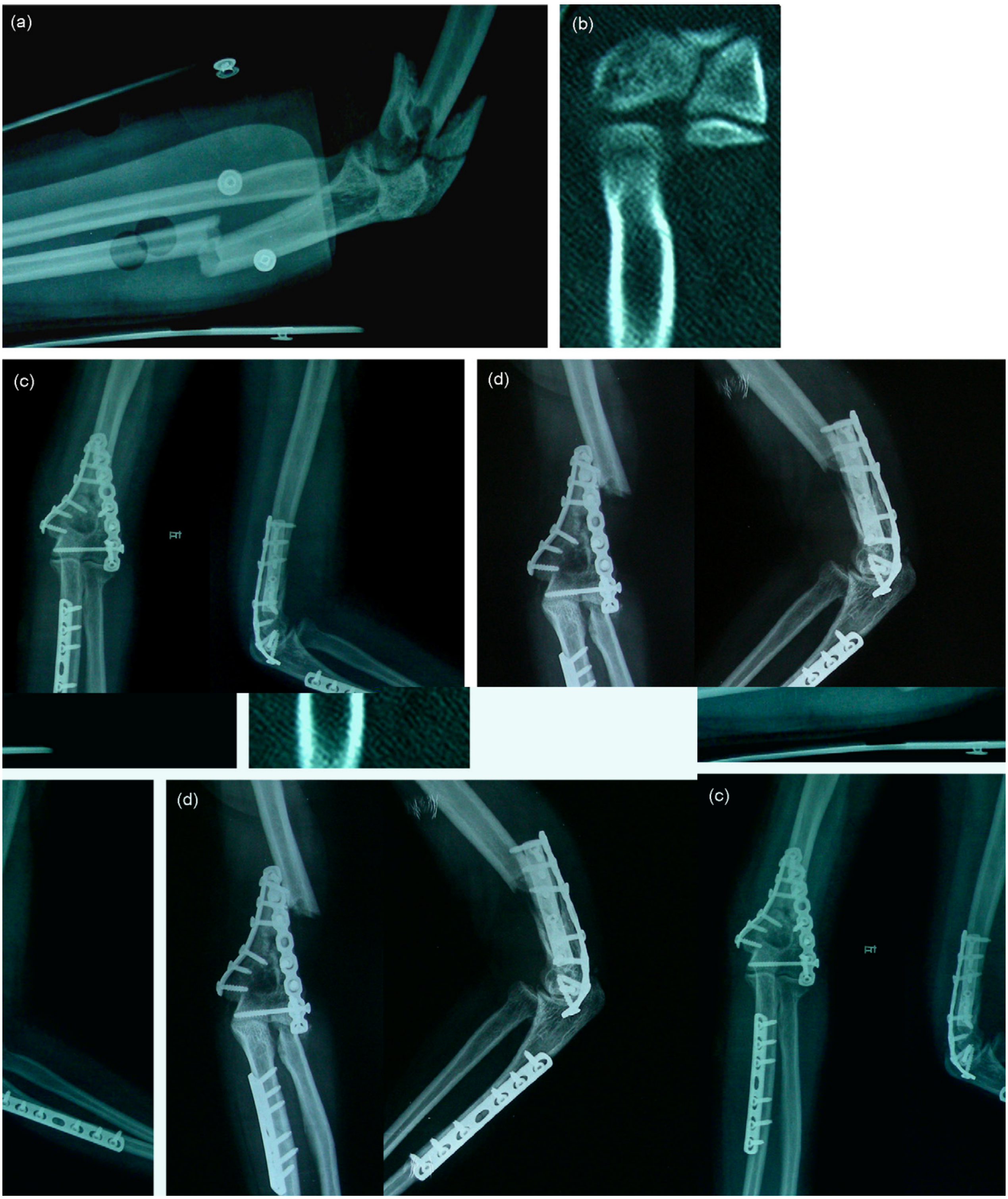

Fig. 4. Lateral radiographs show an intra-articular fracture of the distal humerus (13C2 OTA) associated with a Monteggia fracture in the ipsilateral upper extremity. (A) Computed tomography demonstrates that the fracture involved the articular surface. (B) Open reduction with internal fixation was performed through medial and lateral elbow incisions and, 3 months after the operation, the fracture was clinically united; subluxation of the proximal radio-humeral joint was noted. (C) A humeral shaft fracture was found at the proximal end of the plate after the patient's second fall. (D) Open reduction with internal fixation was performed through the initial lateral incision and fixed with a 4.5-mm dynamic compression plate after removal of the posterolateral reconstruction plate. (E) All the fractures had united 12 months after the second operation. (F) The surgical incisions. (G) Final function of the affected elbow.

Fig. 4. (*Continued*).

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